# ELEMENTARY COURSE

OF

# PRACTICAL SCIENCE

## PART I

BY

HUGH GORDON, M.A. OXFORD, ETC.

SCIENCE DEMONSTRATOR TO THE LONDON SCHOOL BOARD; SCIENCE LECTURER
TO THE SURREY COUNTY C

WITH ILLUSTRATIONS



London
MACMILLAN AND CO.
AND NEW YORK
1893

# PREFACE

THIS book is the outcome of work carried on under my superintendence in some fifteen schools under the London School Board during the last two and a half years, and is based on a scheme drawn up by Professor H. E. Armstrong, Ph.D., F.R.S., in the Second Report of a Committee of the British Association "Upon the Present Methods of Teaching Chemistry." I am glad of the opportunity of acknowledging at the same time my indebtedness to Professor Armstrong for very many invaluable suggestions.

The plan of the course is based on the assumption—with which most must agree—that the value to be assigned to science teaching in Elementary and Continuation Schools should depend, not so much on the immediate utility of the knowledge imparted to the scholars, as on its educational effect. It must be remembered that the aim at this stage should be to teach the youthful scholars the art of helping themselves—of thinking about what they

see and do—and of working exactly and with an object. With this special end in view the metric system was introduced into the first few pages of the book, as being a simple means of indicating the methods to be pursued in the investigation of any subject whatsoever, and further, of pointing out in what manner the powers of observation and reasoning may be most easily developed. Objections have often been raised on the score of the special practical skill required in carrying out such a scheme as is embodied in this work, but surely the time has passed for objections of this kind to be of any weight. Science had much better be left alone altogether than be taught unscientifically. Much greater harm is sure to arise from its abuse than from its omission. Are drawing, carpentry, washing, and cooking, etc., to be taught by those who have had no practical experience in such subjects? Such a question needs no answer. With how much greater force does this reasoning apply to the teaching of science. Hitherto too much has been learnt from text-books, too little from personal experience. Science teaching, to be of any value, must be practical from *the very commencement.*

Is there, therefore, any remedy for the undoubted lack of practical knowledge on the part of the teachers? As teachers at present are obliged to

pay attention to so many different subjects, it may well be asked, how are they to acquire practical skill and confidence in teaching any one of them? The only answer that need be given to such a question is, that it has been, and therefore can be, done. To teach science effectively, the teachers must at times live, as it were, in an atmosphere of science; they must meet together, not only to improve themselves in experimental work, but also to discuss methods and points of interest, and further, must be kept in touch with what is going on in the scientific world, especially with regard to educational questions. This can most easily be done by the holding of classes in some central position, and by the constant meeting at these classes of those who are engaged in the work. I am firmly convinced that it is to the teachers in the Elementary Schools, and not to specialists, that we must in the future look for the instruction of special subjects, *always provided that* their work in the schools be thoroughly supervised by one who not only understands the subject and *its aim*, but is at the same time in sympathy with them and their work.

During nearly three years I have held classes for teachers taking this scheme in their schools, and in addition have constantly inspected—once a month at least—all such schools, asking questions, looking

at note-books, examining in practical work, inspecting apparatus, and giving help in difficulties, and have found it possible in this way to correct mistakes and to stop the growth of bad habits. The results so far have more than fulfilled my expectations.

The importance to be attached at the present time to some really practical scheme of this kind cannot be over-rated, owing to the great development which has lately taken place in so-called Technical Instruction. Not one of the least difficulties to be met with in the forwarding of Technical Education lies in the fact that at present so much has to be unlearnt before work of any real value can be commenced. Bad habits and careless reasoning soon become engrained, and are then with difficulty removed. In the future the work must be judged by its quality and not by its quantity. The efficiency of Technical Education must and always will depend to a *very large extent* on the work done in the Elementary and Continuation Schools, and for this reason it is therefore of the utmost importance that the science taught in all schools should indeed be *science*, and not an agglomeration of facts and unscientific methods.

As to other objections which have been raised at various times on the score of special appliances, cost, accommodation, etc., experience satisfies me that there is no insuperable difficulty in this direction.

In the first place, the apparatus should not be of an elaborate or expensive kind; the simplest contrivances should be used, and originality both of teacher and pupils developed by the construction of their own appliances. The only really expensive item is the balance, and this *must be good*, as not only does the whole work depend on it, but its proper use inculcates habits of the utmost importance—habits of accuracy and care which will in time be found to pervade the whole of the after work. The very fact that most of these delicate instruments in use in my classes are almost in as good a state of preservation as when supplied, speaks much for the care taken of them by the users, and it should be remembered that in many cases they have been used by over 150 boys during the space of two and a half years. Only a small extra amount will have to be set apart for breakages, as most of these can be replaced at a trifling cost. As to room accommodation; so far an ordinary class-room with a few tables—in many instances only one—has been found amply sufficient, but it is to be hoped that, as the importance of the work is recognised, rooms with fittings of the very simplest description will be specially set apart for practical work.

I cannot conclude without referring to the importance of including some such scheme of practical lessons

in the work undertaken in the girls' schools. Who can walk through a kitchen or a laundry without being immediately struck with their close resemblance to an ordinary laboratory? and surely those employed in them would be much better fitted for carrying on such work as cooking and washing after having passed through a preliminary training in scientific method. The majority of the illustrations in the book were drawn for me by Mr. John Goodfellow, to whom I am much indebted for the same.

## CONTENTS

### Distillation



### Filtration



### Evaporation



### Solubility



### Appendices

# INTRODUCTION

In drawing up the following scheme of practical instruction in science the aim has not been to impart a knowledge of a large number of more or less disconnected facts, but rather to teach the methods which should be used in ascertaining facts. Facts are at this stage to be valued on account of what they teach or of what may be learnt during their acquisition. They are to be considered as vehicles for developing the powers of observation, reasoning, etc. Careful and personal observation should be followed by the deductions which can be drawn from such observations. For this purpose it is of first importance that the scholars should be taught how to make experiments themselves, and how to make use of any knowledge thus acquired in attacking more difficult problems.

The method of teaching should be that of suggestion combined with a minimum amount of demonstration —that of asking questions, not of answering them. In short, the pupil should be put in the way of questioning Nature herself, and of understanding her answers.

It is essential that their conclusions should at first be based *only* on those facts with which they have themselves been brought into personal contact. At

a later period the work of others will have to be studied, but there will then be a clearer and more just appreciation of its value and trustworthiness.

Dependence on themselves and confidence in their own work should be stimulated as much as possible by constant practice.

*Try for yourself*, arrange an experiment to find out, should at first be the one answer to all questions. More time will of course be required for such work, but who can doubt how infinitely greater will be the educational value of such a mode of procedure. Throughout life we are called on to help ourselves, and why should not children be systematically trained to help themselves in acquiring knowledge?

Great stress throughout has been laid on accuracy—a point which has hitherto been too much neglected, and which cannot fail to save much time and trouble in later work.

In my own experience, during several years, I have been much struck by the pleasure and satisfaction aroused in youthful scholars on obtaining consistent and accurate results—a characteristic which, together with that of originality, they appear to lose in after years. The reason of this loss is not far to seek; what more direful influence could possibly be exercised on the development of such powers than the constant appeal to memory and the consequent inattention to the development of other faculties? For such reasons formulæ and definitions should at first, at all events, be eschewed as much as possible.

# TO THE TEACHERS

IN carrying this scheme into practice, a lesson of about 40 minutes should be given *at least* twice a week.

A short demonstration and explanation of the subject-matter before each set of exercises should be given, and the scholars then set to work out practically, and enter in their note-books, the answers to the questions. It is hardly to be expected that in Elementary and Continuation Schools every pupil will be able to do all the experiments, but it has been found practicable for *the class as a whole*—exclusive of the teacher—to carry out the work required in answering the whole set of questions.

The Experiments should be described and answers to the questions should be entered in a note-book by every scholar—as is explained in the footnote to page 9—no matter whether the corresponding experiment has been done by himself or by others in the class. Too much stress cannot be laid on the habit of recording all results in this way.

The experiments should be made by the scholars in turn. The most convenient way is to take them

schools which have sufficient apparatus and a room set apart for science teaching, the practical work should be carried out by each boy individually. For scholars in polytechnics, etc., so much time will not have to be devoted to Part I., but still it is of some importance that it should be worked through before commencing Part II., as the latter depends to a great extent on the knowledge acquired and the methods used in Part I.

In conclusion, great attention should be paid to the manner in which the experiments are conducted. Everything should be done as well as possible; there should be no hurry or carelessness. The apparatus should be scrupulously clean; any extra time spent in this way is never misspent, and will in the long run save much time and dissatisfaction, and give rise to habits which will be of the utmost use later on in life.

# TO EXAMINERS

As one of the chief points in the following scheme is the practical work, it is essential that the examination be partly practical. It has been found convenient in examining large classes of between 60 and 70 to divide them into three equal sets and to examine these separately, giving

a set (1) practical work ;
,, (2) a paper on theoretical work ;
,, (3) a *vivâ voce* examination.

In practical work two scholars may be set to work together, and should at the completion of the experiment hand in a full description of what they have done, and the results they have arrived at.

In gauging the results much may be learnt by glancing through a few of the note-books in which the work of the year has been recorded. Such a mode of procedure is certain to stimulate the interest and pride of the scholar in his own individual work.

# SCIENCE PRIMERS

## MEASUREMENT

### Measurement of Length

§ 1. **The English System.**—Describe a footrule.

Here is another ruler, on which are certain marks or divisions; look at it carefully and see how it is divided. The two edges are divided differently. Have you ever met with any of the lengths before?

EXPERIMENT[1] 1.—Take your footrule, which you know to be divided into inches, and place it by the side of the new ruler. What do you notice? One edge is divided into inches. Into how many parts are these divided? Count—the inches are divided

[1] The word experiment is derived from the Latin *experimentum*, trial.

each into 10 equal parts. Each part is therefore one-tenth of an inch, and may be written $\frac{1}{10}$ or 1/10 inch; the figure 1 being placed over the 10 to indicate that the inch is divided into 10 equal parts, and that one of these parts is taken.

Look at your footrule again. Into how many equal parts are the inches on it divided? Into 12 on one side and 16 on the other. How are these to be written? Surely in a similar manner, that is to say, in the former case each part should be written $\frac{1}{12}$ inch, and in the latter $\frac{1}{16}$ inch, and so on.

§ 2. **The Decimal System.**—One inch, one orange, or any one object, may be written as follows—

One inch or 1 inch
One orange or 1 orange.

But here is a length somewhat longer than an inch, say one inch and one of the parts marked on the measure on which the inches are divided into tenths.

How is this to be written? Why, as follows—

1 inch and 1 tenth part.

EXPERIMENT 2.—Make various measurements and put them down in this way—

| | Inches. | Tenth Parts. |
|---|---|---|
| Length of copy book = . | 8 | 1 |
| Breadth „ „ . | 6 | 4 |
| Another length . . | 3 | 7 |
| Add these together—they become | 17 | |

But 12 tenth parts are 1 inch and 2 tenth parts, the result is therefore 18 inches and 2 tenth parts.

But this is not a simple way. Suppose we shorten it by placing some mark to divide the inches from the tenth parts. Let us use a stop or dot, and write thus—

| | | | | | | |
|---|---|---|---|---|---|---|
| 1·1 inch | instead of | 1 inch | and | 1 | tenth | part |
| 8·1 inches | „ | 8 inches | „ | 1 | „ | part |
| 6·4 „ | „ | 6 „ | „ | 4 | „ | parts |
| 3·7 „ | „ | 3 „ | „ | 7 | „ | parts |

When therefore a point is placed in front of a number it changes its value altogether.

Thus—

·1 inch does not mean 1 inch, but 1 part
·2 inches „ 2 inches, but 2 parts

when 10 parts = 1 inch.

This is therefore a short way of expressing the fact that an inch has been divided into 10 equal parts, and that in one case 1 and in the other 2 parts have been taken.

Here is another example. Add the following together—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2·4 inches, | or | 2 in. | and | 4 | tenth | parts to |
| | 1·5 „ | „ | 1 „ | and | 5 | „ | parts |
| The result is | 3·9 „ | „ | 3 „ | and | 9 | „ | parts. |

Is this correct? Try for yourself as follows.

Experiment 3.—Draw a line 2·4 inches long and then continue it 1·5 inches, now measure the

whole line. How long is it? It is 3 inches and 9 tenth parts, or shortly 3·9. Work out other examples. Work out also some examples subtracting a part from the whole line. Thus take 4 inches from a line 7·6 inches long—the result is 3·6 inches.

7·6
4·0 or 4 inches and no parts.
———
3·6

Try for yourself and find out if this is the case.

It has been agreed to use this method for separating the tenths from the wholes, and it is called for this reason the **Decimal System**, from the Latin word *decimus*, tenth.

§ 3. **The English Standard of Length.**—How are rulers such as we have used made? How does the maker know what length to mark off? What is an inch? What is a foot? etc. Are they always the same? How are they found out, and why are they used? Consider for a moment what would happen if every one had different measures, and that a foot was the length of any one's foot; what confusion there would be. No one would know for certain the length of anything. To overcome this difficulty, and to prevent confusion as to correct measurements, *Standards of Length* have been made.

**The Standard of Length in England** is the distance between two fine scratches on a certain bar of metal kept in the Houses of Parliament. This

distance is called the **Imperial Yard**. A length equal to the standard yard is generally if not always

divided into 36 equal parts, which are called inches, 12 of which make a foot.

1 yard = 3 feet = 36 inches.

§ 4. **French Standard of Length.**—The French Standard is not the same as the English, and is divided differently.

It is again the distance between two fine lines on a metallic bar, but this distance is called the **Metre**.[1] It is divided into 10, 100, 1000, etc., equal parts.

A tenth part of a metre is called a decimetre or dm. (from *decem* = 10).
A hundredth part of a metre is called a centimetre or cm. (from *centum* = 100).
A thousandth part of a metre is called a millimetre or mm. (from *mille* = 1000).

A decimetre being a tenth of a metre is ·1 metre.

Is it possible to use the same kind of notation to describe a hundredth and also a thousandth part, namely, a centimetre and a millimetre? How is this to be done?

1 centimetre, or $\frac{1}{100}$th of a metre, cannot be written ·1 metre, as this indicates a decimetre, a

[1] From the Greek *metron*, a measure.

centimetre being a tenth part of this. The different parts might be placed in different columns, thus—

| | Metres. | Decimetres. | Centimetres. | Millimetres. |
|---|---|---|---|---|
| (1) | 1 | 1 | 1 | 1 |
| (2) | 3 | 5 | 4 | 2 |
| (3) | 4 | 0 | 0 | 8 |
| (4) | 3 | 1 | 0 | 6, etc. |

But 10 mm. make 1 cm., and must therefore be placed in the centimetre column as 1 cm. Again, 10 cm. = 1 dm., and must therefore be placed in the dm. column as 1 dm., etc. Is it not possible to write the figures in a shorter and simpler way?

How many millimetres are there in each of the above examples?

Take (1). Here we have—

| | | |
|---|---|---|
| 1 metre | = | 1000 mm. |
| 1 dm. | = | 100 „ |
| 1 cm. | = | 10 „ |
| 1 mm. | = | 1 „ |
| Total | = | 1111 mm. |

How can you express this in metres? Surely by dividing by a thousand, 1000 mm. being 1 m. Now think how you multiply by 10, by 100, or by 1000. Is it not by putting an ought at the end every time the number is multiplied by 10?

Thus—

$2 \times 10 = 20$ or $2{\cdot}000 \times 10 = 20{\cdot}00$

$2 \times 100 = 200$ „ $2{\cdot}000 \times 100 = 200{\cdot}0$

$2 \times 1000 = 2000$ „ $2{\cdot}000 \times 1000 = 2000{\cdot}$

That is to say, in multiplying by 10 the decimal point is moved one place to the right, by 100 two places, and by 1000 three places, and so on. Take a more difficult case.

| | | | |
|---|---|---|---|
| | $2{\cdot}111 \times 10 =$ | $21{\cdot}11$ | or one place to the right |
| and | $2{\cdot}111 \times 100 =$ | $211{\cdot}1$ | ,, two places ,, |
| | $2{\cdot}111 \times 1000 =$ | $2111{\cdot}$ | ,, three ,, ,, |
| | | | and so on. |

How are you to divide by 10, 100, and 1000 on the same principle? Surely by reversing the operation, that is, by moving the decimal point one place to the left.

| | | | |
|---|---|---|---|
| Thus— | $2000{\cdot} \div 10 =$ | $200{\cdot}0$ | or one place to the left |
| | $2000{\cdot} \div 100 =$ | $20{\cdot}00$ | ,, two places ,, |
| | $2000{\cdot} \div 1000 =$ | $2{\cdot}000$ | ,, three ,, ,, |

Does this method give correct results? Yes.

Again take 2111· and divide by 10, 100, and 1000 thus—

$$2111{\cdot} \div 10 = 211{\cdot}1$$
$$2111{\cdot} \div 100 = 21{\cdot}11$$
$$2111{\cdot} \div 1000 = 2{\cdot}111$$

Now go back to your examples in millimetres. Here is 1111 mm.

| | | | |
|---|---|---|---|
| Divide by | 10 | and they become | cm., as 10 mm. = 1 cm. |
| ,, | 100 | ,, ,, | dm. as 100 mm. = 1 dm. |
| ,, | 1000 | ,, ,, | m. as 1000 mm. = 1 m. |

Here is the result—

| | | |
|---|---|---|
| 1111 mm. | = | 111·1 cm. |
| ,, | = | 11·11 dm. |
| ,, | = | 1·111 m. |

Express the other examples in metres and parts thus—

| | | | |
|---|---|---|---|
| (2) | 3542· mm. | becomes | 3·542 m. |
| (3) | 4008· mm. | ,, | 4·008 m. |
| (4) | 3106· mm. | ,, | 3·106 m. |

But how are you to divide say 1· by 1000? Surely in the same way, by moving the decimal point three places to the left, thus—

| | | |
|---|---|---|
| 1· ÷ 10 | = | ·1 |
| 1· ÷ 100 | = | ·01 |
| 1· ÷ 1000 | = | ·001 |

This being the case

| | | | | |
|---|---|---|---|---|
| 1 m. | | = | 1· | m. |
| 1 dm. or metre ÷ | 10 | = | ·1 | ,, |
| 1 cm. ,, ÷ | 100 | = | ·01 | ,, |
| 1 mm. ,, ÷ | 1000 | = | ·001 | ,, |

Express the following in metres and parts of a metre, and then add them together.

| | | | |
|---|---|---|---|
| 11· mm. | = | ·011 m. | (3 places to left) |
| 145 cm. | = | 1·450 ,, | (2 places to left) |
| 6·1 dm. | = | ·610 ,, | (1 place to left) |
| Total | = | 2·071 m. | |

**Note.**—The divisions on the other edge of your measure are centimetres, and these, as you will notice, are divided into 10 parts; each of these is therefore ·1 centimetre or a millimetre.

Experiment 4.—Mark out on the Black Board a line 100 centimetres in length, and then measure off on it a yard.

Is the metre longer or shorter than the yard? How many inches is it?

§ 5. It is of **very great importance** to learn to think in the metric system, that is to say, to be able to judge a length, say in centimetres, quite apart from any other system. You have always your measures before you; *well use them.* Here is a slate, how many centimetres long is it? Guess, then measure it. How long is your middle finger in centimetres? guess again, and then measure it.

**Do not** first guess the length in inches and then calculate from that, but try to guess in centimetres.

Spread out your hand as far as possible and measure in centimetres from the tip of your little finger to that of your thumb. This will give you a rough method of estimating short distances in centimetres.

## Exercises [1]

1. Describe your measure, its appearance, and state, if possible, what wood it is made of, if hard

[1] Each scholar should be supplied with a copy book, in which to enter the answers to *every* question. The number of the question or exercise should be placed before each answer, and in the accounts of work done by other scholars the name of the experimenter should be in brackets. The answer should be recorded as follows—

Exercise 11

The weight of the 2 cm. cubes.

| | | | |
|---|---|---|---|
| Poplar | = | 9·37 grammes | (A. Smith) |
| Ebony | = | 2·93 " | (J. Brown), etc. |

The account should be written in such a way as to express all that was done, showing that the experiments, etc., *were* carried out by or in the presence of the writer.

or soft, the colour, and how it is divided. Make a sketch of it, giving also a section. In fact, describe it in such a way that any one could pick it out from a number of other measures.

2. Draw a picture of a measure in your books 6 inches long and 1 inch broad, having the upper edge divided into inches and tenths, the lower divided into centimetres and tenths.

3. Place three dots, A B C, in your book. Measure their distance from one another in inches and parts of an inch (using the decimal system) and in centimetres and parts of a centimetre.

4. What is the name of the standard of length in England and of that in France? Describe the Standards themselves, and make a drawing showing what they are like (refer to Fig.) In what way are these lengths generally divided?

5. Measure your height in centimetres and record it in your book; also the size of your head, first measuring it with a piece of string. Who has the largest head and who the smallest?

6. How many steps do you take walking across the playground? What is the length of your step, and what is roughly the distance across the playground?

**§ 6. Measurement of length and breadth or surface.**—A pane of glass is broken, how is the glazier to know the size of the glass he is to bring?

It is clear he must be told not only the length but also the breadth.

How will you find out how much glass is required? Make the following experiments to ascertain this.

EXPERIMENT 5.—Draw on the board a square 1 foot long by 1 foot broad; this may be called a square foot. Draw also squares 2 feet by 2 feet, and 3 feet by 3 feet. How many square feet will each of these contain? Try for yourself. Divide them as below.

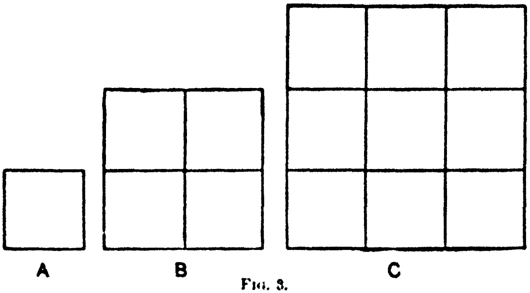



FIG. 3.

Here B contains 4 square feet and C 9 square feet. They can be divided into rows as above. Now as there are two rows in B, and as each contains 2 square feet, there must be 4 square feet. In C there are 3 square feet in each row and 3 of these rows, therefore there must be 9 square feet. It is easily seen that the length of the top gives the number of square feet in a row, and the length of the side the number of rows. What do you conclude from this? Surely that the

number of square inches, feet, etc., in a square or oblong can be found by multiplying the length by the breadth, or the number in a row by the number of rows. The numbers so obtained give the surface or area in square inches, feet, etc.

The areas in the above examples were therefore 4 and 9 square feet respectively. How would you find out the number of penny stamps in a sheet? Surely in the same way, by counting the number in a row, and then the number of rows.

### Exercises

7. Draw in your books (1) An inch square.
(2) A centimetre square.

8. Draw squares of the following sizes :—

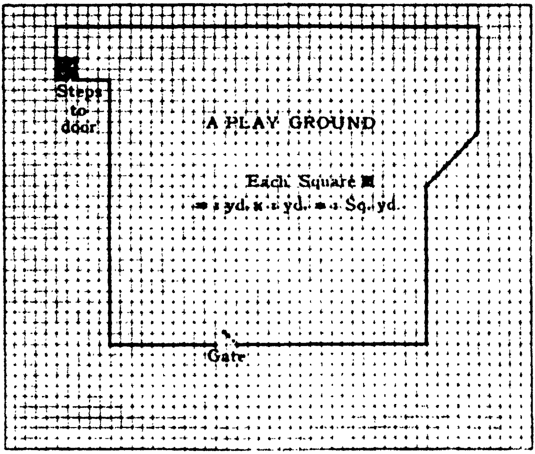
(1) 3″ × 3″ and divide into square inches—how many are there?

(2) 4 cm. × 4 cm. and divide into square cms.—how many are there?

9. Find out how many square feet the black board contains.

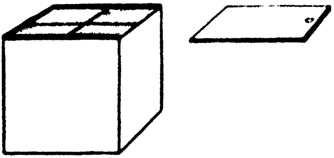
10. What is the area of your schoolroom in square feet? Make a diagram of your playground, marking out the lengths of the different sides.

This might also be mapped out on squared paper, the side of each square representing a yard, and the squares therefore square yards. How many square yards are there in the playground?




A Playground.

**§ 7. Measurement of bulk or volume.**—Here



is a box packed full of small cubes, how many does it hold? Eight.

The edge of the box is only twice that of the cubes, but it holds eight of them. What name is to be given to these cubes, which are an inch in every

direction? Surely each may be called a cubic inch of wood. In the same way a cube 1 cm. in each direction may be called a cubic centimetre.

How can you find out the number of cubic inches or cubic centimetres in a given block of wood?

Here are two cubes, the edge of one, B, is 2 inches, while that of the other, A, is only 1 inch.

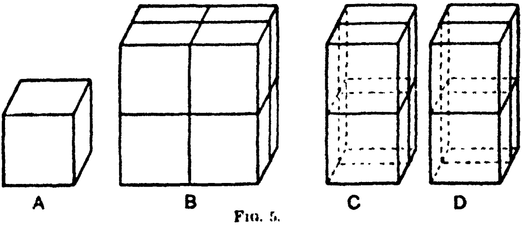



FIG. 5.

Build up with the inch cubes A, a cube B, the edge of which is 2 inches.

How many inch cubes does it take? Eight.

Break this cube up into slices one inch thick, as C and D. Each slice contains 4 cubes.

How are the number of slices to be found? By measuring the thickness. One inch thick giving one slice C, two two slices, C and D, and so on.

How can the number of cubes in a slice be found? Surely by first finding the area of the slice. Try this for yourself. What do you conclude from this? Of course that the bulk or volume can be found by multiplying the length by the breadth and by the thickness.

### Exercises

11. Describe an inch cube, making a sketch of one. How many cubic centimetres does it contain? Measure and find out.

12. How many cubic centimetres are contained in the large cubes (the 4 cm. cubes) supplied? Measure and find out.

13. A biscuit tin is 12 inches long by 5 inches broad and 6 inches deep inside. How many cubic inches of water will it hold? How many cubic centimetres?

§ 8. **Measurement of weight.**—You have already seen the necessity of having standards of length, and for the same reason you will understand why there must be standards of weight. The most convenient is the **French or metric system** of weight, which is used by men of science, and also in many countries by all.

§ 9. **The English system of weights.**—The standard of weight in England is made of a metal called platinum. It is cylindrical in form, about 1·35 inch in height and 1·15 inch in diameter, and is kept with the standard of length. The weight of this cylinder is called a **pound.**

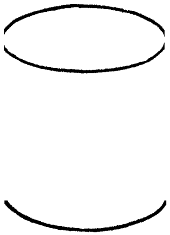


Fig. 6.
The Imperial Pound.

Smaller weights are made by the subdivision of a weight equal to the pound. This is sometimes

divided into 12, sometimes into 16 ounces, etc. Refer to your arithmetic.

§ 10. **The French system of weights.**—The French starting-point is called a gramme (how it is obtained will be discovered later), but being small, the Standard which is kept is 1000 times as heavy. The French in the subdivision of this weight again make use of the decimal system.

The gramme or gram is therefore divided into

| | | | | |
|---|---|---|---|---|
| 10 parts, each called a | decigram | (dg.) = | 0·1 | gram. |
| 100 ,, | ,, centigram | (cg.) | 0·01 | ,, |
| 1000 ,, | ,, milligram | (mg.) = | 0·001 | ,, |

Thus the following weights can be written—

| grams. | dg. | cg. | mg. | mg. | grams. |
|---|---|---|---|---|---|
| 10 | 5 | 4 | 6 | 10,546 = | 10·546 |
| 8 | 3 | 9 | 5 | 8,395 = | 8·395, etc. |

Refer back to the subdivision of length and compare the two.

## ADDITIONS OF INTEREST

The following is an extract from *St. James's Gazette*, 4th April 1892 :

### THE PARLIAMENTARY "STANDARDS"

#### WHAT THEY ARE AND HOW THEY ARE TESTED

**An interesting ceremony took place on Saturday at the House of Commons, when an official examination was made of the copies of the imperial yard and**

pound which are immured at the Houses of Parliament. There were present the Speaker, Colonel Carington (representing the Lord Chamberlain), Sir Michael Hicks-Beach (President of the Board of Trade), several of the chief officers of the Houses of Parliament and Board of Trade, including Mr. Chaney, the Superintendent of the Standards Department, and Mr. H. W. Chisholm, late Warden of the Standards, one of the two surviving members of the late Standards Commission in whose presence the last examination was made in 1872.

These Standards were originally immured in 1853 in a recess of the wall on the east side of the Lower Waiting Hall of the Houses of Parliament. In 1864 it was found that the imperial standard pound, which was originally enclosed in a mahogany box lined with leather fixed with glue, was discoloured by the decomposition of the glue in that damp situation. It was consequently deemed expedient to examine the parliamentary copies, including the immured Standards. All were, however, found uninjured, and precautions were taken against any such further occurrence. In 1870 some alterations were made in the Lower Waiting Hall, and the immured Standards, contained in a strong oak box, were temporarily removed to the Standards Office. They remained there until 1872, when they were deposited in a recess on the right-hand side of the second landing of the public staircase leading from the Lower Waiting Hall up to the Commons Committee Rooms.

On the present occasion—twenty years having elapsed since their deposit—it was deemed expedient by the Board of Trade to examine the condition of these immured Standards; and this was accordingly done on Saturday morning. The stone covering the recess having been previously removed, and the oak box containing the Standards placed on a bench in front of it, and the President of the Board of Trade having explained the objects of the meeting, the box was opened by Mr. Chaney and the standard yard removed to the bronze platform of a comparing apparatus provided with two micrometer microscopes, and, having been placed alongside of the Board of Trade parliamentary copy of the imperial standard yard, was compared with it by Mr. Chaney. The comparing apparatus had been specially constructed for the purpose, in order to avoid the removal of the immured Standards from the Houses of Parliament. A special balance had also been constructed and enclosed in a brass case, to which the standard pound No. 4 was removed for comparison and compared with the Board of Trade parliamentary copy of the imperial pound. Mr. Chaney then announced that he found that there was no difference equal to the one-hundred-thousandth part of an inch between the standard yards or of one-thousandth part of a grain between the standard pounds, and that their condition was quite satisfactory. The immured Standards were then restored to the recess to be again closed up, and an official report of the process ordered to

be prepared, with the view of being laid before Parliament. The ceremony was thus brought to a close.

The existing imperial standards of the yard and the avoirdupois pound were constructed in 1845, under the directions of the Commission for Restoration of the Standards, to replace those destroyed at the burning of the Houses of Parliament on the 16th of October 1834. The Commission was appointed on the 20th of June 1843; Sir G. B. Airy, the late Astronomer-Royal, being chairman. The direct superintendence of the construction and verification of the standard of length was entrusted to Mr. Bailey, and after his death to Mr. Sheepshanks; that of the standard of weight to Professor W. H. Miller: all being members of the Commission and of the Royal Society.

In addition to the new imperial standards of the yard and pound, four parliamentary copies of these standards were constructed, to be available, in the event of the destruction or injury of the new imperial standards, for their restoration. The standard yards consist of a solid square bar of bronze or gun-metal thirty-eight inches long and one inch square in transverse section. The defining lines of the yard are cut on a gold stud, $\frac{1}{10}$ inch in diameter, inserted at the bottom of a cylindrical hole sunk to half the depth of the bar one inch from each end of the bar.

A number of experiments were made for determining the sort of metal to be used in con-

structing the new standard yard. It had to be so durable as to form, as far as possible, an invariable measure, and consequently to be hard, so as to break without bending when external force was applied to it. The bronze alloy finally adopted, and known as Bailey's metal, consists of copper 16 parts, tin $2\frac{1}{2}$ parts, zinc 1 part. The imperial standard yard No. 1 has its true length at the temperature of 62 deg. Fahr. The four parliamentary copies and their standard temperature are as follows:—

No. 2, at 61·94 deg., deposited at the Royal Mint.

No. 3, at 62·10 deg., deposited with the Royal Society.

No. 4, at 61·98 deg., immured at the Houses of Parliament.

No. 5, at 62·16 deg., deposited at the Royal Observatory, Greenwich.

The coefficient of expansion of 36 inches of these bronze bars for 1 deg. Fahr. was determined to be 0·000341 in. The immured standard yard was consequently only seven millionths of an inch longer than the imperial standards, and the nearest to it of all the four parliamentary copies. These standard yards were cast in 1845 by Messrs. Troughton and Simms. The imperial standard yard is enclosed in a fire-proof iron chest made by Messrs. Chubb and Co., and is deposited, together with the imperial standard pound, in the strong room in the basement of the Standards Office. The parliamentary copies are placed in strong oak boxes.

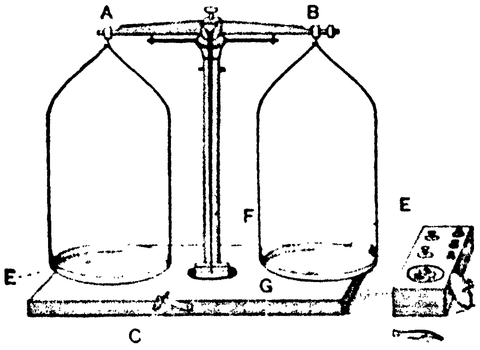
The new imperial standard pound avoirdupois and its parliamentary copies are constructed of platinum. They are cylindrical in form, about 1·35 in. in height and 1·15 in. in diameter, and are enclosed in a small silver-gilt case inside a strong bronze box. There is a slight difference in their density, and their true weight is in a vacuum.

No provision for the periodical comparison of these Standards with the imperial standards and with each other was made by the Standards Act of 1854; but the amending Standards Act of 1866 provided that such comparison of the parliamentary copies at the Mint, the Royal Society, and the Observatory at Greenwich should be made every ten years. No such provision was, however, contained as to the Standards immured at the Houses of Parliament.

Under the Weights and Measures Act, 1878, an additional copy both of the imperial standard yard and pound was constructed for the use of the Standards Department, in order to avoid the use of the imperial standards in official comparisons; and they were deemed to be additional parliamentary copies as established by the previous Act. These were the standards used on this occasion for the comparison of the immured parliamentary copies.

*Note.*—What is the meaning of 62 deg. Fahr.? You do not know. Do not at present attempt to find out, but keep it in mind in the hope that you may be able to explain it later. Surely these figures are recorded for some purpose.

§ 11. **The Scales**[1] **or Balance.**—How would you be sure that a grocer had sold you a pound of tea? Surely you would weigh it in the scales. Here is a much better balance or scales than is commonly used. Look at it carefully. It[2] consists of the beam A, B, which can be raised or lowered by the handle C. This beam is supported in the




middle on a sharp edge. At each end of the is hung a pan E, E, also resting on a sharp edge at A and B. There is also a small screw nut at B, and

[1] Why do we call the instrument with which we weigh scales? Look in the dictionary. From what is the word derived? Much may be learnt in this way. Refer to a dictionary in all cases of doubt, and make a note in your book giving the reference. Such words as oscillation, index, etc., should all be looked up in this way. The *Imperial Dictionary* is included in most Public Libraries, and will be found very useful for such purposes.

[2] The balance should be set up before the class.

a pointer or index F, moving in front of a small scale G.

§ 12. In the case of delicate scales, the following **Method of Weighing** should be used. The *object* to be weighed *should always be placed in the left-hand pan and the weights*[1] *in the right.* The box of weights should be placed on the right hand side of the balance for convenience. The weights must not be touched with the fingers, but only with the *forceps*, so as to keep them always dry and clean. *Always lower the beam* before adding or taking off a weight.

EXPERIMENT 6.—Raise the beam by the handle C, and notice if the index moves over the same number of divisions or degrees on each side. If this is not the case move the screw-nut backwards or forwards till the oscillations are equal, *lowering the beam each time before moving the nut.* Now place in the left-hand pan a 10 gram weight, and then beginning with the heaviest, place the other weights in the right-hand pan in order, without missing any.

After adding each weight raise the beam and notice the index. When the index oscillates the same number of degrees on each side of the scale, look at the weight in the right-hand pan. How much is it? It is also 10 grams. Now place in the pan, in addition to the 10 grams, the smallest weight (10 mg. or ·01 gram). Does the index oscillate equally? No. Try other experiments with 100

[1] This is done for convenience, as most of you will use your right hand to take up the weights.

grams, etc.—the same result is always obtained. What do you conclude? Surely that *when the index swings on each side of the scale the weights in each pan*

It is therefore easy to ascertain the weight of any object by placing it in one pan and weights in the other—when the weights are equal the index will swing equally on both sides.

§ 13. **Important Note.**—The following rules should always be observed in weighing.

1. Place the small weights on a specially divided piece of paper, or scratch divisions on the woodwork of the balance thus—

| | |
|---|---|
| ·1 | ·1 |
| ·01 | ·01 |

2. See that the balance is swinging correctly before starting.

3. Place the object to be weighed in the left-hand pan, and then starting with the largest weight you think necessary add in succession the other weights without missing any, removing those which are too heavy before adding the lighter ones.

4. When the weighing is finished, write down the weights missing from their places and which ought therefore to be in the right-hand pan. In replacing them note if your first reading is correct. *This always be done.*

*Example.*—The following weights were found to be missing from their places:—

10·00
5·00

·10
·05
·02

15·67 grams.

On replacing the weights the same result wa obtained; the above amount was therefore correct.

EXERCISES

14. Weigh each of the large cubes (4 cm. cubes) and each of the small cubes (2 cm. cubes) in French grams and parts of a gram.

15. Tabulate the above in the order of their weights. What do you notice? Surely that equal sized cubes of different woods have different weights.

16. Find out how many times heavier the different cubes of woods are than the cube of the lightest wood of the same size.

*Example.*

Weight of small Ebony cube = 9·37
" " Poplar " = 2·93

or $\frac{9\cdot37}{2\cdot93} = 3\cdot19$

Therefore Ebony is 3·19 times as heavy as Poplar.

The numbers so obtained can be called the *Relative Weights* of the woods in comparison with that of Poplar.

17. How much larger are the 4 cm. cubes than the 2 cm. cubes? Find out roughly by taking the weights of the two cubes of the same wood and ascertaining how many times heavier the one is than the other.

18. Find out how many grains go to a gram, and the weight in grams of one ounce.

§ 14. **Graphic Representation of the weights of the cubes.**—Could you represent the weights of the cubes and therefore of the different woods in any other way than by numbers? Why not by straight lines? The heavier cubes or woods by the longer straight lines. Do this.

*Example.*—Take the small cubes, and represent 1 gram by a line 1 cm. long.

Therefore as Ebony = 9·37 gms. it is to be represented by a line 9·37 cm.

Therefore as Boxwood = 6·33 gms. it is to be represented by a line 6·33 cm.

Therefore as Poplar = 2·93 gms. it is to be represented by a line 2·93 cm.

Draw the lines.

Do the same with the large cubes, only in this case 1 gram may be represented by 1 mm. or any convenient length: a note of this being made at the side as in the former case.

(This should be shown to the class on a larger scale on the black board.)

§ 15. **The Weight of Water.**—We have already found out the weights of various woods; let us now ascertain the weight of a definite volume of water. Here is a cubic centimetre measure. Find out the weight of 64 cubic centimetres of water, that is, the weight of a cube of water of the same size as the large cubes of wood.

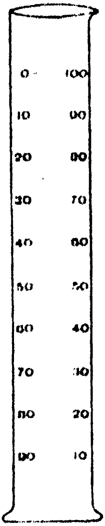


FIG. 8. The Cubic Centimetre Measure.

EXPERIMENT 7. -Weigh a medium sized beaker with a lip. Measure out 64 cc. of water in the measuring glass and pour it into the beaker. How much does it weigh? Nearly 64 grams. How much, therefore, would 1 cc. of water weigh? About 1 gram. Is this the case? Empty the beaker, and *weigh* out 50 grams of water and then measure it. It measures nearly 50 cc. What do you conclude from this? That the gram is very nearly the weight of 1 cc. of water

## ADDITIONS OF INTEREST

### THE METRIC SYSTEM

"The report to the French National proposing this was presented 17th March 1791

meridian measurements finished and adopted 22nd June 1799, an intermediate system of division and names 28th May 1812, abolished and pure decimal system enforced 1st January 1840. Since then Netherlands, Spain (1850), Italy, Greece, Austria (legalised 1876), Germany, Norway and Sweden (1878), Switzerland, Portugal, Mexico, and other States have adopted this system. The use of it is permissive in Great Britain, India, Canada, etc. The theory of the system is that the metre is a 10,000,000th of a quadrant of the Earth through Paris; the litre is a cube of $\frac{1}{10}$ metre; the gramme $\frac{1}{1000}$ of the litre filled with water at 4° C."—*Encyclopædia Britannica*.

## Exercises

19. Represent graphically the weights of the different cubes.

20. Also represent graphically the *relative weights* of the above woods compared with lightest, that is, poplar. Thus, if Poplar is represented by 1 dm., Ebony should be represented by a line 3·19 dm. long.

21. Weigh 20 cc. and also 100 cc. of water. What is the result?

22. About how much does 1 cc. of water weigh? Calculate from your last result.

23. What is the size of the large cubes, and what is the weight of an equal volume of water? Try yourself.

## THE LEVER

§ 16. **Experiments with a simple balance or lever.**—You have now become accustomed to the use of the balance. How is it that equal weights balance one another? Make some experiments yourself to find this out. Use a two-foot rule and balance

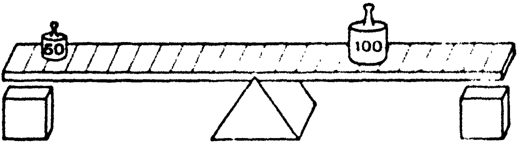



FIG. 9. The Lever.

it on a prism of wood, resting the middle of the ruler on the edge of the prism as shown in the illustration.

EXPERIMENT 8.—If it does not balance make it do so by fastening a loop of wire of the right weight on one end. You know that in your good balance 10 grams are balanced by 10 grams, place therefore 10 grams on the left-hand end and then another 10 grams on the right-hand end.

What do you notice? That these weights do not balance one another *unless* they are placed at the same distance from the middle of the ruler, or from the edge of the prism on which it is swinging. This edge is called the **Fulcrum.** What do you conclude? Surely that equal weights only balance at equal distances from the fulcrum. Is this always the case?

Try. The above fact might suggest to you the probability of unequal weights balancing one another if at different distances. Try this.

EXPERIMENT 9.—Take a 10 gram and 20 gram weight, and put the 10 grams at 12 inches, then carefully adjust the 20 grams so as to balance the 10. When it balances it, what is its distance from the fulcrum? 6 inches, or 10 grams at 12 inches balances 20 grams at 6 inches. Try other experiments and put down the results.

| | Weight. | Distance. | | Weight. | Distance. |
|---|---|---|---|---|---|
| Thus— | 100 at | 12 | balanced | 200 at | 6 |
| | 50 ,, | 12 | ,, | 200 ,, | 3, etc. |

What do you conclude from this? That the heavier weight has to be placed nearer the fulcrum. But more than this, namely, that twice the weight has to be at half the distance, four times the weight at a quarter the distance. The distance is therefore inversely as the weight, or the one weight multiplied by its distance must be equal to the other weight multiplied by its distance, if they are to balance one another.

The numbers so obtained (weight $\times$ distance) are called the *moments*.

Thus the moments in the first experiment are

$$10 \times 12 = 120, \text{ and } 20 \times 6 = 120, \text{ etc.}$$

Therefore when the moments are equal the weights will balance one another.

### Exercises

24. Find out *by experiment* with the above lever what weights at the distances 1, 2, 4, and 5 inches will be required to balance 10 grams at 10 inches.

25. Calculate what weights would be required

| | | | |
|---|---|---|---|
| (i.) | at a distance of 4 cm. | to balance 8 g. | at 8 cm. |
| (ii.) | " " 6 cm. | " 10 g. | " 24 cm. |
| (iii.) | " " 10 cm. | " 6 g. | " 6 cm. |

26. Draw a picture of the lever with which the above experiments were made.

**§ 17. Application of the above conclusions to the Balance.**—You have already discovered with your simple lever that the greater the distance a weight is from the fulcrum, the greater weight it will balance on the opposite side or arm. If the lever is not properly balanced before starting, how could you bring this about? Surely by hanging a loop of wire to one arm, and moving it backwards or forwards until the lever assumes a horizontal position. Try this. Have you not noticed the small nut at the end of the right-hand arm of the balance? May it not be for the same purpose? Try some experiments to see if this is the case.

Experiment 10.—Unscrew the nut on the balance till it is at the end of the screw, then raise the beam. What is the result? Screw it in as far as it will go, what happens in this case? In the first experiment the right-hand pan is weighed down, whilst in the latter the opposite effect takes place. By careful

adjustment, therefore, the two pans can be made to balance one another.

From the foregoing experiments with your lever what do you conclude? Surely that the two arms of the balance must be of the same length if equal weights are to balance one another in the two scale pans.

EXERCISES

27. Weigh the cubes of wood with the lever, using a 10 gram weight.

28. A plank of wood 10 feet long is balanced in the middle on the side of a tub—calculate at what distance boys, weighing respectively 5, 6 and 7 stone, would balance a weight of 3 stone at the other end.

## THE RELATIVE WEIGHTS OF LIQUIDS AND SOLIDS

§ 18. **Relative weights of liquids.**—You have already seen that cubes of different woods of the same size are of very different weights. Further, you have compared these weights with the weight of the lightest, namely, Poplar. The numbers so obtained were called the **Relative weights compared with Poplar.** Thus the relative weight of Ebony was 3·19, that is to say, it was 3·19 times as heavy as Poplar. Try now to find out the weights of equal bulks or volumes of the various liquids you know. How is this to be done? As you cannot cut out

cubes of different liquids, some other course must be adopted. Why not fill a bottle with the liquid and weigh it? The weight of the bottle being subtracted, the remainder will be the weight of the volume of liquid which filled the bottle. How are you to fill the bottle to the same extent each time? Surely by putting in the stopper. But then a little air is sometimes pushed in, and the stopper does not always fit in easily. How is this difficulty to be overcome? Nothing simpler. File a nick or passage along the stopper through which the liquid can run out as the stopper is pushed in.

§ 19. **The Relative weight bottle.**—Wash out with water and then dry[1] an ordinary 2 oz. bottle fitted with a glass stopper, filing a small nick or passage along the stopper with a three cornered file wetted with turpentine or spirit (see illustration). Carefully weigh the bottle and stopper. Fill with water and put in the stopper. Some of the water will pass through the passage so that the bottle can be filled each time to the same extent.

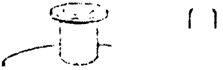


Fig. 10. The Relative Weight Bottle.

Turn the bottle upside down, and see if there is any

[1] Glass bottles, tubes, etc., can be quickly dried by washing them out with methylated spirits, and then warming over a bunsen and blowing air into them by a pair of

air in it; if so, refill and try again. Dry the bottle outside and then weigh it. What is the weight of the water? This is easily found out by taking away the weight of the bottle from the weight of the bottle full of water. Do this with other liquids. The weights of equal volumes of different liquids can be found out in this way, and the problem is solved. What liquid will you take as your standard in comparing these weights? Will it not be best to take water, as it is always at hand. Calculate, therefore, how many times heavier or lighter the liquids are than water—that is, find out the **relative weights of the liquids compared with water.**

EXPERIMENT 11.—Here are the results of an experiment which was made.

**The Relative weight of milk** (water = 1)

| | | |
|---|---|---|
| Weight [1] of bottle + water | = | 170·18 |
| Weight of bottle | = | 113·51 |
| Weight of water | = | 56·67 |
| Weight of bottle + milk | = | 172·00 |
| Weight of bottle | = | 113·51 |
| Weight of milk | = | 58·49 |

$$\text{Therefore relative weight of the milk} = \frac{58\cdot49}{56\cdot67} = 1\cdot032$$

The milk is therefore 1·032 times heavier than water.

[1] It will be found convenient to write the weight of bottle and of water on a label and attach it to the bottle with a piece of string, so that the label may be taken off when any weighings are made.

The relative weight of a liquid, that is to say, its weight compared with that of an equal bulk of water, is

$$= \frac{\text{weight of some volume of the liquid}}{\text{weight of an equal volume of water.}}$$

## Exercises

29. Find out the relative weights of milk, warm water, oil.

*Note.*—In the case of milk and warm water the bottle should be first rinsed out with the liquid and then filled. In the case of oil, on the other hand, it must be washed and dried as already explained.

30. Which is the heavier, hot or cold water, bulk for bulk?

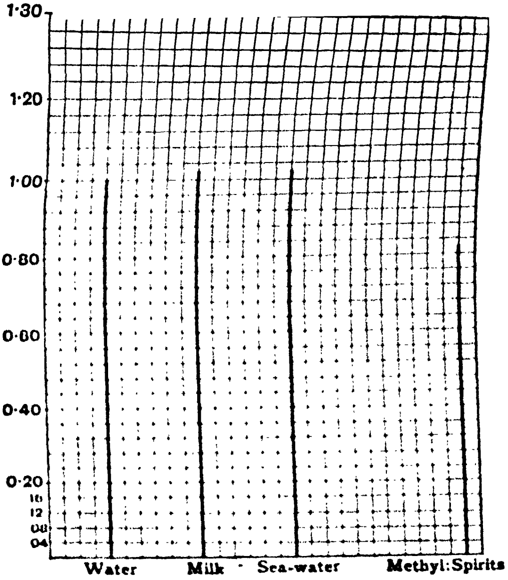
31. What did you notice when the bottle full of warm water had cooled? What do you conclude from your observation?

32. Find the relative weights of the following liquids—beer, coffee, tea, sea-water, vinegar, methylated spirits, petroleum, etc.

33. Find the relative weight (1) of a mixture of milk with an equal volume of water, (2) of a mixture of methylated spirit with its own bulk of water.

34. Tabulate your results.

35. Represent graphically on squared paper the relative weights of the liquids examined, in the way shown on the following




The Relative Weights of Liquids

§ 20. **Relative weights of liquids by means of the U tube.**—Is it possible to determine the relative weights of liquids in any other way? Why not take equal weights and notice their volumes? Try this in the following way and compare the results with those already obtained.

EXPERIMENT 12. **The U tube.**—Take two glass tubes A, B, about 12-15 inches long and about ¼ inch internal diameter. Soften both ends in a flame, to prevent the edges cutting the india-rubber tubing.

Then after thoroughly cleaning and drying (see footnote, p. 33), join the tubes by a piece of india-rubber tubing E. Mount the whole on a board as shown in the diagram, fixing the tubes by means of two india-rubber bands C C, and two rectangular pieces of cork G G, and a piece of cork at F. Draw on the board the line D, and fix above it with two drawing-pins a paper millimetre scale. This scale will serve to measure heights above D, and need only extend from about A to G. Draw out a glass tube in a burner and cut it at A; then soften the ends in the flame. This is called a *pipette*, and can be used for introducing the liquids. Suck up some mercury into the pipette, and after placing your finger on the top, transfer sufficient to the tube B to reach the base line D. The mercury can now be used as a pair of scales, and various liquids can be weighed one against the other in the two tubes A and B. See what happens when water is poured into the two tubes. When the columns are of the same height the mercury also stands at the same height in both tubes. Take another example. A column of water 300 mm. in

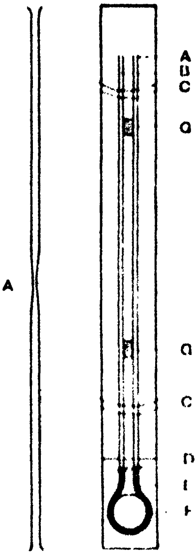


FIG. 11. The U Tube

height is found to balance a column of a certain liquid 150 mm. in height. Which is the heavier liquid? Surely the latter. How many times heavier? Evidently twice, as the column of water has to be twice as long as that of the liquid before they balance one another.

The following account of an experiment with milk will explain how by this method weighings should be carried out.

EXPERIMENT 13.—The mercury was first filled in up to the line D, and after pouring water into tube A with the pipette, milk[1] was gradually added to the other tube until the mercury was at the same height in both tubes, *i.e.* opposite the base line D.

The heights of the columns were read off and found to be—

water column 264 mm. } *i.e.* 264 mm. of water
milk „ 257 „ } balanced 257 mm. of milk.

Which is the heavier liquid bulk for bulk? Clearly the milk, as 257 mm. balance 264 mm. of water. In what proportion is it heavier? Evidently in the proportion of the lengths of the two columns.

$$\text{But } \frac{264}{257} = 1{\cdot}027$$

So that the milk is 1·027 times as heavy as water, in other words, its relative weight is 1·027 (water = 1).

You thus find out the relative weight of a liquid (water = 1)

[1] The pipette should be first rinsed out with the milk.

$$= \frac{\text{length of water column}}{\text{length of liquid column}}$$

*Note.*—Fairly accurate results can be obtained by this method if the mercury and tubes are clean and dry at starting. The measurements must of course be accurately made.

The apparatus can be easily taken to pieces and the tubes cleaned and dried after each experiment.

EXERCISES

36. Find the relative weights of milk, sea-water, methylated spirit, oil, petroleum, etc., by means of the U tube.

37. Compare the results with those obtained in any other way. This should be done by writing down the results side by side in two columns.

## THE BAROMETER

§ 21. **The U tube and the air.**—In your last set of experiments, what did you notice after introducing the mercury? That it came to exactly the same height in both the open tubes. Attach a piece of india-rubber tubing to one tube and suck out some of the air. What happens? The mercury rises in that side. It will be interesting to find out what happens when all the air is withdrawn. Try this in the following way.

EXPERIMENT 14.—Connect the glass tube F F,

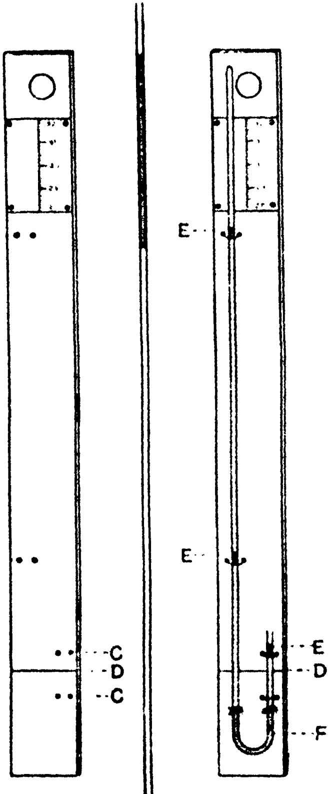



FIG. 12.—The Barometer.

FIG. 13.
Porcelain Dish.

which is closed at one end, by means of a piece of india-rubber tubing F to the open glass tube E F.[1] The india-rubber tubing should be tied on to the glass tubes by string to prevent it slipping off. Carefully clean[2] and dry some mercury, and then pour it from a porcelain dish into the tube in the way shown in the illustration. After carefully shaking to remove air bubbles from

[1] This must of course be softened in the burner.

[2] Dry the mercury by stirring it with a piece of blotting paper, and then pour it through a funnel-shaped piece of paper with some pin-holes in it.

the tube place your finger at the open end F, and arrange the tubes on the board which is supplied. This board is about 38 in. long, and has a base line D marked on it and a scale B showing the number of inches and tenths (28-32 in.) above D. Holes are bored at C C C C, through which wire can be passed to fasten the tubes to the board. The tube E F should be loose enough to allow of an up and down movement, by means of which the mercury can always be brought to the same height, *i.e.* to the line D. What do you notice? The mercury in E E is about 30 in. above the mercury in E F. There must therefore be something pushing down on the surface of the mercury in E F sufficient to balance the 30 in. of mercury in E E. There is nothing but air in contact with the mercury in the open tube, and the air cannot get at the mercury in the closed so you will at once say—Why, it can only be the air. Now what would you expect to happen if the air became heavier or lighter? In the former case would not the air be able to support a longer column of mercury, while in the latter the effect would be the opposite? How are you to ascertain if this is the case? Surely by trying.

EXPERIMENT 15.—Attach a piece of india-rubber tubing to E; blow down it and so force air in. What happens? The mercury rises in E E. Reverse the experiment, *i.e.* suck air out of E, now the mercury sinks. What are you doing in the two cases? Surely only increasing the weight of the air in the

former, and in the latter decreasing it. The results are what you expected. You have therefore a U tube with air in one limb and mercury in the other, and by watching the mercury from day to day you will be able to ascertain whether any change takes place in the weight of the air. For this reason such an instrument is called a **Barometer** (*baros* = weight, *metron* = measure). The mercury in E F should always be brought to the same level, *i.e.* to D, by moving the limb E F, thus allowing the direct reading of the height of the mercury in E E above that in E F.

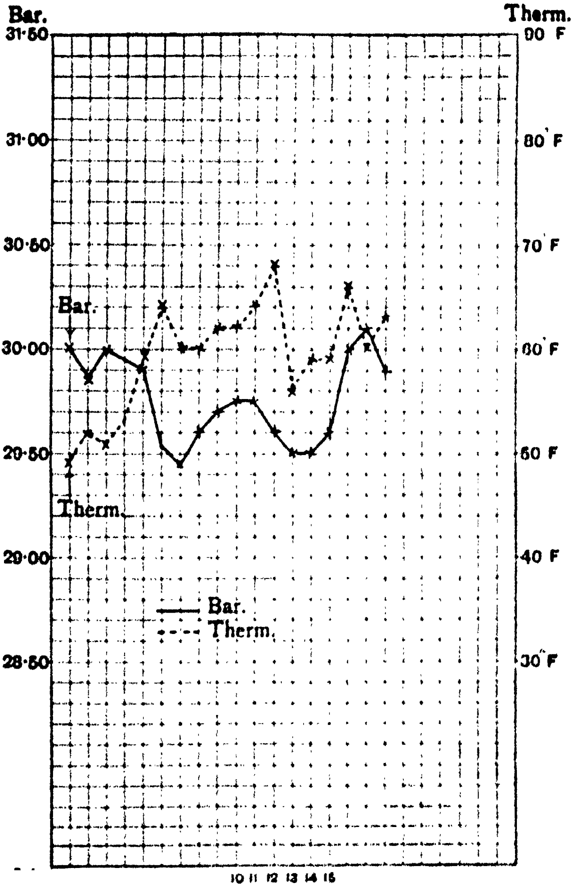
### Exercises

38. Take the readings of the barometer as often as possible, and compare your results with those recorded in the newspapers.[1]

39. Map out your results graphically on squared paper, an example of which is given on the opposite page. The height should only be represented by dots, which are then to be joined by lines. This may be called the barometric curve.

40. Describe the barometer, and explain how you would make one, giving diagrams.

[1] Your readings will be about ·4" lower than those recorded in the newspapers, as it is impossible to remove the last traces of air by the above method.


Bar.
Therm.
31·50
31·00
30·50
30·00
29·50
29·00
28·50
90 F
80 F
70 F
60 F
50 F
40 F
30 F
Bar.
Therm.
Bar.
Therm.
10 11 12 13 14 15

## ADDITION OF INTEREST

The following is an extract from *The Morning Post*, 1st June 1892:—

### THE HURRICANE IN MAURITIUS

PORT LOUIS, 12*th May* 1892.

Friday, the 29th of April last, will long be remembered as an eventful day in Mauritius. Between the hours of noon and 6 P.M. the island was subjected to a terrible cyclone, surpassing in violence any that have been previously known, for it overthrew about one-third of Port Louis, killing several hundreds of people and maiming thousands. Property to an immense amount all over the island has been destroyed, accompanied by heavy loss of life, and it is fearful to contemplate the result had the storm burst upon us by night instead of by day. The whole summer had been unusually hot. It began at an earlier period than usual, and the heat continued long after the time when, in ordinary circumstances, cool weather might be expected. During this season there had been disturbances occasionally approaching dangerously near our coasts, but relatively harmless. There was one in January, another in March, each followed by a temporary fall in the thermometer, but the continued stillness and closeness of the atmosphere gave rise to troublous thoughts and uneasy minds, the more so because the coming on of winter, which should have brought the looked-for coolness, in no

way allayed the intolerable heat. To get over the first half of April without a storm was generally considered a safe sign. From this time forward it seems impossible to reckon on security in any part of the year. Intense heat was experienced on the 27th, followed by a most oppressive night. Few could sleep, and the distant roar of the waves dashing on the coral reefs was clearly heard miles inland. The heavy surf next day and the constant heat were evidence that something unusual was taking place not far off. Friday morning broke cloudy and stormy, and every one was aware that bad weather was in the vicinity; but as it is always the unexpected that happens, no man apprehended the reality, and all business people, according to custom, went to work in Port Louis, leaving their wives and families in the country. By half-past ten all who could do so quitted town by the last down train destined to run that day, and so far they were lucky. The wind was coming in ominous gusts, with driving rain, but telegrams from the Royal Alfred Observatory spoke of danger as unlikely, and predicted that the wind would never exceed 56 miles per hour, and that in any case the storm would be of short duration. Hurricanes rarely approach Mauritius from the north-west, and hence the Director of the Observatory was misled. Crowds assembled at the Central Railway Station hoping to get away, but two trains were due in Port Louis before the 1.30 down train could start. Neither of these trains was heard of; the telegraph

wires were broken, and it was impossible without information to risk a collision. The would-be travellers, nearly all of them fathers of families, were consequently obliged to await events, which took no long time in shaping themselves. Suddenly, about noon, with a furious hissing noise, the pent-up storm rushed in from the north-west. Fragile buildings soon gave way, tin roofs were ripped off, stout trees uprooted, and for an hour and a half the whole town and country was exposed to a pitiless tornado, accentuated by a deluge of rain. *The barometer, which all the morning had been gradually falling, suddenly dropped an inch in two hours till it reached its lowest point,* 27·96; it then as suddenly began to rise, showing that the depression was passing away from us, the wind without warning lulled, the clouds dispersed, and a bright sun shining in a blue sky proclaimed apparently that the tempest had subsided, and that all sense of peril had passed away. People accordingly began to look about, and it was soon noised abroad that the sea had passed her bounds, and was well up on shore towards Government House. Huge lighters were floating where an hour before there had been dry land, and boats were plying on a new sea. The Post Office, the Custom House, the Oriental Hotel, were standing like islands in a fresh-formed flood. Men went, some to business, some outside to see the effects of the storm, thinking that all was over. The more experienced shook their heads, expressing the belief that we were in a fool's paradise, and that the quiet calm was a portentous

prelude to worse to come. There was nothing to show the state of things one way or another. Again, without one sign of warning, and from a direction precisely opposite to its former course, the wind seemed as it were to burst out of the calm with tenfold violence. For two hours or so, from three o'clock until after five, it maintained its fury, blast succeeding blast, each worse than its predecessor, and filling men's hearts with fear. In the presence of such mighty factors human power felt its utter impotence. How long the terror would last none could tell, but, judging by the earlier blow as the cyclone approached, its duration would be short. At the Observatory the pressure was registered at 73 lbs. to the square foot, equal to a velocity of 121 miles per hour. The centre passed six miles to the west of the Observatory, or precisely over Port Louis, and it is consequently fair to infer that the velocity upon the town was greater. Whether the registered velocity of the wind is of any practical value for explaining its results is not now to be considered. The question in this instance for experts to decide is why the effects were so disastrous, and whether the position of the town, lying at the foot of a belt of hills, did not aid the wind, which was reflected with greater force from the mountainous barrier that opposed its volume. By six o'clock all was nearly quiet. Gusts still came up at ever-increasing distances, and at greater intervals. But the heavens were clear and the stars peeped forth, and people then began to breathe again.

§ 22. **The Relative weights of solids.**—You have already found out the weights of various liquids compared with water. How can you ascertain the same thing in the case of solids? Do you clearly understand what you wish to do? Is it not simply to find out how many times heavier a solid is than an equal volume of water? What would happen if you were to drop some nails into a bottle full of water? Try. The nails push out or displace an amount of water equal to their own bulk or volume—evidently no more, no less. How are you to find out the weight of this displaced water? Surely by the loss of weight which takes place after dropping in the nails. The following is an account of an experiment which was carried out in this way.

Experiment 16.—The nails and the bottle full of water were weighed separately.

| | |
|---|---|
| Weight of bottle full of water and stopper | 170·18 |
| Weight of nails . . . . . . | 20·42 |
| Together these therefore weigh . . | 190·60 |

The stopper was then taken out and the nails dropped in. The whole was reweighed after replacing the stopper and drying the outside.

| | |
|---|---|
| Weight of nails and bottle full of water . | 190·60 |
| Weight after dropping in the nails . . | 187·97 |
| Weight of water displaced, *i.e.* Weight of a volume of water equal to that of the nails | 2·63 |

Therefore as the weight relatively to water of a substance

$$= \frac{\text{weight of substance}}{\text{weight of an equal volume of water,}}$$

the weight of the nails relatively to water was 20·42

### Exercises

41. Find out the relative weights of nails, screws, glass rods, slate pencils, etc.

*Note.*—The above substances should be tied together and kept for further experiments (see Experiment 18).

42. What were the volumes respectively of the nails, screws, etc., used in the last experiments? Note that 1 gram of water measures 1 cc.

43. Find out the weight of mercury relatively to that of water in the same way.

*Note.*—The mercury should be weighed in a porcelain dish, the weight of which is known.

§ 23. **Relative weights of solids found by first finding their volume.**—You will now understand that the relative weight of a solid can be easily calculated if its volume in cubic centimetres is known, as 1 cubic centimetre of water weighs about 1 gram. Take the following simple example.

*Example.*—The small 2-cm. cube of Ebony weighs 9·37 grams, and its volume is known to be about

8 cc. (see § 7). But a volume of water of the same size (*i.e.* 8 cc.) weighs about eight grams.

Therefore the weight of Ebony relatively to water

$$\frac{\text{weight of ebony}}{\text{weight of equal volume of water}} \quad i.e. \ \frac{9{\cdot}37}{8{\cdot}00} = 1{\cdot}17.$$

But how can you find out the volume of an irregular solid? Why not by immersing the solid in water and noticing how much the water rises?

The following account of an experiment explains the method.

EXPERIMENT 17.—20 grams of sulphur were added to 50 cc. of water in a measuring glass.

| | |
|---|---|
| Height of water before introduction . | 50 cc. |
| " " after " . | 60 cc. |
| Therefore volume of sulphur | = 10 cc. |

but 10 cc. of water weighs about 10 grams.

Hence weight of sulphur compared with water.

$$\frac{\text{weight of sulphur}}{\text{weight of equal volume of water}} \quad i.e. \ \frac{20}{10} = 2.$$

*Note.*—This is only *a very* rough method, as the measure only indicates cubic centimetres.

## EXERCISES

44. Find out the relative weights of stones, slate pencils, etc., by the above method.

45. Describe how you would find out the volume of a watch-chain; also of some sand.

**§ 24. Relative weights of solids by weighing in water.**—You have noticed that some objects sink when placed in water, and that others float. Of course those which float are supported altogether by the water, but what about the others? Does the water support them at all? Try for yourself by weighing them both out of the water and in the water.

EXPERIMENT 18.—Place the small cross table H H, over the left hand pan, and a beaker[1] on it.

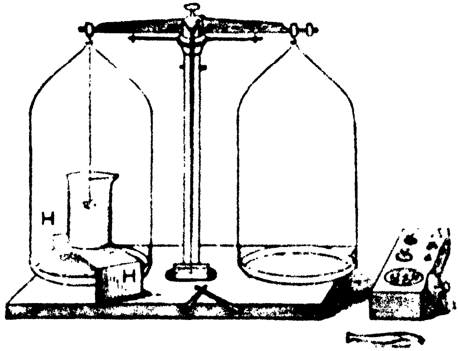



FIG. 14.

Tie together with a fine piece of wire[2] the nail used in Exercise 11, and hang them from the beam so

[1] not so liable to get br
[2] A piece of wire of
and pan to balance the

that the bundle comes inside the beaker but does not touch it. Weigh the nails. Then fill the beaker with water and weigh again.

Here is the result—

| | |
|---|---|
| Weight of nails . . | 20·42 grams. |
| Weight of nails in water . | 17·79 grams. |
| Loss of weight = | 2·63 grams. |

What do you notice? The nails lose in weight, and on reference to Experiment 16, that the loss of weight is equal to the weight of water displaced from the bottle, *i.e.* the weight of a volume of water equal to the volume of the nails. Try the same experiment with the glass rods, screws, etc., used in Exercise 14. What is the result, and what do you conclude? Have you not proved that the loss of weight in water is equal to the weight of an equal volume of water?

Should this be the case the 2-cm. Ebony cube ought to weigh about 8 grams less in water than in air. Try. Is this the case? Yes.

Therefore the relative weight (water = 1) =

$$\frac{\text{weight of substance}}{\text{loss of weight in water.}}$$

The relative weight of the nails is therefore

$$\frac{20{\cdot}42}{2{\cdot}63} = 7{\cdot}76.$$

## Exercises

46. Draw up a table of substances which (*a*) sink, float in water.

47. Ascertain the relative weights compared with water of a sovereign, shilling, florin, and a penny, also of glass, copper, zinc, iron, etc., by the above method.

48. A small 2-cm. cube weighs exactly 10 grams. What would be its weight in water? Give reasons for your answer.

49. Calculate the volumes of the objects used in Exercise 47.

Here is an example—

| | |
|---|---|
| Weight of a coin . . | 14·12 |
| Weight of a coin in water . | 12·76 |
| Loss of weight | 1·36 |

That is, a volume of water of the same size as the coin weighs 1·36 grams, but 1·36 grams of water measures about 1·36 cc.

Hence the volume of the coin is 1·36 cc.

50. Write down in a table the relative weights (water = 1) of all the substances with which you have experimented.

*Note.*—The term **Relative Density**, and also **Specific Gravity**, is used when the relative weights are compared with some standard. Water is the standard used in the case of solids and liquids.

The following is a table of the Relative Densities or Specific Gravities of various substances. Compare them with your own results by putting them side by side in your note-book.

## Table of Relative Densities or Specific Gravities

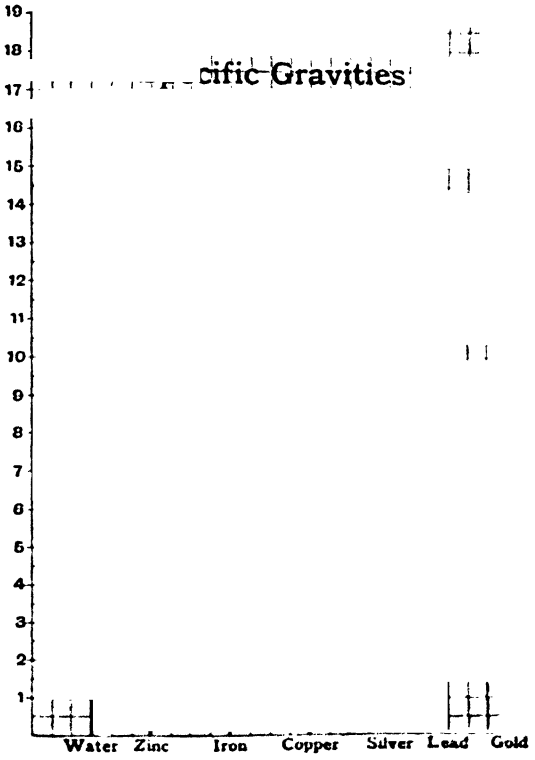
Water at 4° C. = 1

| | |
|---|---|
| Methylated spirits . | 0·825 |
| Naphtha . . . . | 0·848 |
| Olive oil . . . . | 0·915 |
| Sea water . . . | 1·026 |
| Milk . . . . | 1·032 |

SOLIDS

| | | | |
|---|---|---|---|
| Poplar . | 0·389 | Steel . | 7·8—7·9 |
| Oak . | 0·845 | Tin . . | 7·5 |
| Sand . | 1·42 | Brass (cast) | 7·8—8·4 |
| Glass . | 2·5—3·0 | ,, wire. | 8·5 |
| Diamond . | 3·53 | Copper . | 8·6—8·9 |
| Zinc . | 6·8—7·2 | Silver . | 10·5 |
| Iron . | 7·0—7·8 | Lead . | 11·5 |

Gold . . . . 19—19·6


cific Gravities
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Water
Zinc
Iron
Copper
Silver
Lead
Gold

## THERMOMETERS

§ 25. **The expansion and contraction of liquids.**—Most of you must have noticed an instrument hanging up in your school very like the picture. Have you ever asked yourselves why it is there? Look at it. There is a small glass tube with a bulb at one end containing mercury;[1] this is mounted on a piece of wood marked with divisions and numbers. Have you ever watched the liquid in the tube? Is it always at the same point on the scale? No; surely you have observed that the liquid was higher in the tube in summer than in winter. Why is this? It is hot in summer, cold in winter—perhaps the heat and cold may affect it. Try. Place your warm hand over the bulb. What happens? The liquid rises. Place it in cold water. The liquid sinks. Why is this? Does the liquid get larger when heated and smaller again when cooled? Try and find out if this is the case with some liquid, say ordinary water.

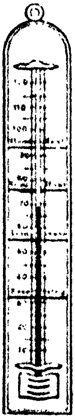


FIG. 15.—The Thermometer.

EXPERIMENT 19.—Fit up a flask with a one-holed india-rubber cork in which is the glass tube A. After filling the flask, gradually push the cork into its

[1] instruments do not always contain mercury, a coloured liquid is often used instead.

place. What happens? Some of the water rises in the tube. A piece of paper should now be attached to the tube to mark the height of the liquid. Set the flask on a retort stand and warm by means of a very small flame. What happens? The water rises and continues to rise. Take away the flame; after a short time the water descends. What do you conclude? Surely that the liquid gets larger or **expands** when heated, and gets smaller or **contracts** on cooling. Now heat some ice-cold water and see what happens (see Exercise 53).

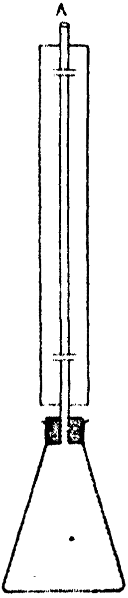


Fig. [illegible]


Fig. 17.

§ 26.—Here is an instrument somewhat similar to that already described but without the wooden scale. Try some experiments with it.

EXPERIMENT 20.—Fit up a test tube with a cork through holes in which are passed one of these instruments A, and also an exit tube B.[1] Half fill the test tube with water and replace the cork. At what height does the mercury stand? Heat the water. What happens? The mercury gradually rises till the water boils, but then

[1] For boring corks, cutting and bending glass tubes, see notes at the end.

stops and remains at one point on the scale. At what height is it? At about 100. Try the opposite effect. Place it in some cold water. Note the height of the mercury, then add some pieces of ice and stir; the mercury now falls. Add more ice and stir. The mercury falls to about 0 on the scale and then remains stationary. Warm the water and again stir. The mercury first ascends and then again comes back to 0. What do you conclude from these experiments? Surely that water boils at 100 on this scale

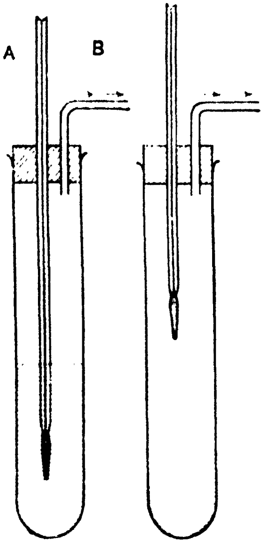



FIG. 18.

ice and water remains at 0. This instrument is called a **thermometer** (*thermos*, hot; *metron*, measure), as it measures the hotness or **temperature**. This particular one is called a centigrade thermometer, as there are 100 degrees or steps (*centum* = 100, *gradus* = step) between the two stationary points at which water boils and ice melts, and we say that

Water boils at 100 degrees or 100 C.[1] (C. = centigrade)
Ice melts at 0 „ „ 0 C.

The thermometer commonly used in England is one invented by a man named Fahrenheit, and called the **Fahrenheit thermometer.** In this the graduations are different. In boiling water the mercury rises to 212, while in melting ice it falls to 32. So —

Boiling point of water = 100 C. or 212 F.
Melting point of ice = 0 C. or 32 F.

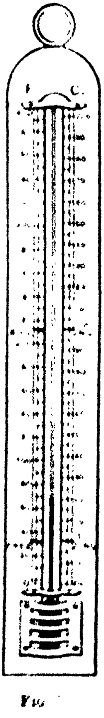



Fig.

EXPERIMENT 21. — Have you ever noticed how the ice-man keeps his ices from melting? Ask him. He tells you with ice and salt. Powder some salt and ice, then mix in a gallipot, and introduce the thermometer; it indicates a temperature many degrees below 0 C. or 32 F.

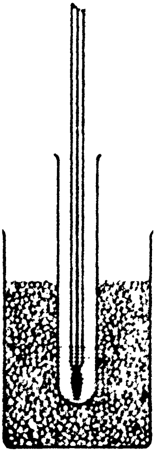


Fig. 20.

EXPERIMENT 22. — Place in the ice and salt mixture a small test tube containing a few cc. of water into which a thermometer dips. Stir the water in the test tube. What do you

[1] The thermometers in general u[...] dom indicate these numbers exactly.

notice? The mercury sinks to 0° C. or 32° F. and then stops, although the mixture outside has been found to be colder than this. Continue stirring. What happens? The water freezes, and then the ice so formed gets colder, *but not till then.* Surely we may therefore conclude from this that water freezes at 0° C. or 32° F.

## Exercises

51. Take the temperature of the room at the same time every day, and plot out the observations on squared paper. Fasten the squared paper in your note books.

52. Take the temperature of the following—
   *a.* Ice and water.
   *b.* Ice and salt, also freezing water.
   *c.* Boiling water.
   *d.* Boiling water containing salt.
   *e.* Boiling water containing sugar.

53. Does water always expand on heating? Make the following experiment to find out. Fit up, as in the illustration, a 4-oz. conical flask with a two-holed india-rubber cork, into one hole of which is fitted a thermometer, and into the other a fine piece of glass tubing about 12 in. long. Fill the flask with ice-cold water and carefully replace the cork; some of the liquid will ascend the tube. Heat carefully with a very small flame. Describe *fully* what happens, noting temperature, etc.

54. At what temperature is water the heaviest?

55. Which is the heavier, water or ice? How do you know this?

56. From your answer to the last question could you tell whether water expands or contracts when frozen? To put it simply: will one pound of water be larger or smaller in bulk when frozen than when liquid?

What happens sometimes in the winter to the water-pipes? Does this support your answer to the first part of the question?

57. A pond is exposed to a cold wind, describe exactly what you think will happen.

*Note.* — Remember that a heavier liquid will sink in a lighter, and that water at 4° C. is heavier than water at any other temperature.

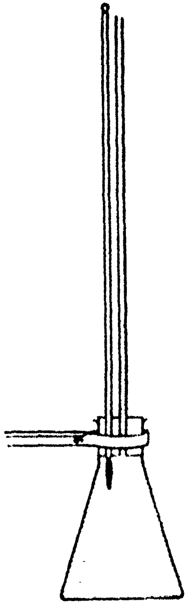


Fig. 21

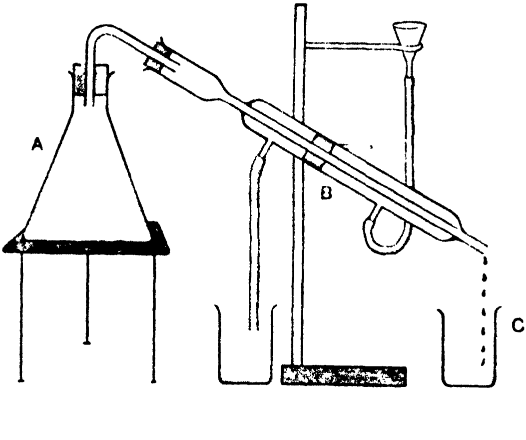
58. Is solid wax lighter or heavier than liquid wax? Melt some in a test tube and find out.

## DISTILLATION

§ 27. **The boiling of water.**—While boiling the water in your last set of experiments, you must

have noticed that it gradually disappeared from the flask, and that at the same time a cloud appeared at the mouth of the flask. Where did the water go to, and what is this cloud? Is this cloud water? if so, can the water be recovered?

EXPERIMENT 23.—Boil some water in a flask and place over it a slate. It becomes wet, and the moisture on it looks like water. Collect some. To do this it will be more convenient to make use of the apparatus shown in the illustration, which consists of a flask A, connected with a tube B, which is surrounded




with cold water. Fill the flask half full of water and boil. What happens?

Is the liquid which collects at C, water? Taste it.

Put a little in a test tube and take its boiling-point. It evidently is unchanged water.

The whole apparatus is called a still (*stilla*, a drop), and the tube B, a condenser,[1] as it condenses the invisible water-vapour into water. The process is called **Distillation**.

What do you think will happen if salt water is distilled? Will the salt go over with the water?

Try. Pour some salt water into the flask and distil. Collect the condensed liquid (or distillate) and test as follows:—

1. Taste—no saltness noticeable.
2. Boiling-point—same as ordinary water.

The salt, therefore, is left behind, and the water can be separated from it in this way.

Dissolve other solids in water and distil. What is the result? What conclusion have you arrived at concerning the distillation of water containing salt, sugar, etc., dissolved in it?

## FILTRATION

§ 28. **The separation of certain solids from water by straining.**—When sand is shaken up with water does it dissolve like salt? No. Shake up some chalk in the same way. It apparently does not dissolve. The chalk settles to the bottom, like the sand, but very slowly.

[1] This particular one is called a *Liebig's Condenser*, because it

Is it possible to separate such substances from water in a quicker way? Try straining through muslin or some material such as blotting paper, through which water will pass.

EXPERIMENT 24.—Here is a glass funnel. Fit into it a filter paper, as is shown in the illustration. Shake up some powdered chalk with water and pour

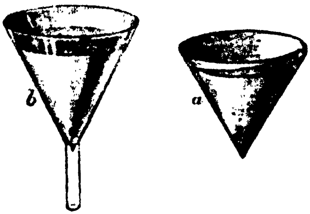



FIG. 23.- Funnel and Filter Paper.

it through the filter paper. What is the result? The chalk is retained on the paper. Will salt water leave the salt behind in the same way? Try for yourself. Does the liquid which passes through (called the filtrate) contain salt? Taste it. Do the same with a solution of sugar.

What do you conclude from these experiments?

## EXERCISES

59. Distil a solution of sugar and salt. Test the liquid before and after the process by—

1. Taste. 2. Boiling-point. 3. Specific Gravity.

Write down in your note-book what results are obtained.

60. Describe and draw a picture of the Liebig's Condenser, and state how it is used.

61. Shake up some sugar and powdered chalk with water. How can you separate the chalk from the sugar? Do so.

## EVAPORATION

§ 29. **Evaporation at ordinary temperatures.** —In your experiments with thermometers did you notice any cloud at the mouth of the flask before the water boiled? Yes; this was clearly the case. Does the water then pass away in vapour, or **evaporate,** at lower temperatures than that of boiling water? Does water evaporate at ordinary temperatures? How can you find out?

EXPERIMENT 25.—Half fill an evaporating dish (see Fig. 13) with water, weigh it, then leave it for a day and weigh again. What do you notice? That it has lost in weight. Must not this be due to the evaporation of some of the water?

How much has evaporated? Does the same amount disappear every day? Try. No; the amounts are different. Why is this? Does more or less evaporate on a wet day? Try to find out by daily observation.

Have you ever noticed anything of the kind

before? Do wet clothes dry more quickly on a damp or dry day? Carefully note down the state of the weather in connection with these experiments.

What are your conclusions about this question?

§ 30. **Sea-weed.**—Here is some sea-weed. At times it does not seem to be so dry as at others. Is this so? How can you find out? You at once answer that if it is drier one day it will also be lighter. Why not weigh it every day and see?

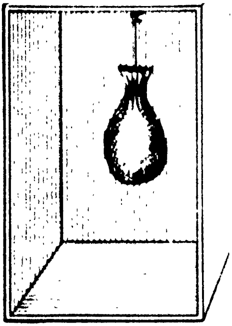


FIG. 24.—Sea-weed.

EXPERIMENT 26.—Make a muslin bag and fill it with sea-weed.[1] Weigh it every day and note down the result. Does it change in weight? See Exercise

§ 31. **The wet and dry bulb thermometer.**—Here is an instrument which consists of two thermometers side by side.

What is it for? Examine it. One thermometer differs from the other in having a piece of muslin tied round the bulb, the other end of which dips into a small glass vessel. What is this vessel for? It

[1] The sea-weed should be hung up outside the window in a small box to serve as a protection against the rain.

is to put water in. Fill it with water. What happens? Some of it runs up the muslin and keeps the bulb wet. Do you notice anything else? Yes. The mercury in the wet bulb thermometer sinks, showing that it is colder than the other. How is this? Surely the water is not colder than the air? Try some experiments to see if this is the case.

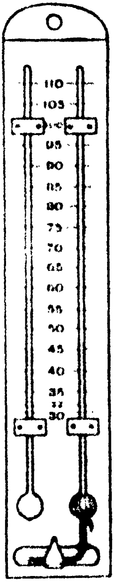


FIG. 2[illegible]. Wet and dry bulb Thermometer.

EXPERIMENT 27.—Fill a beaker with water and leave it until the temperature is the same as the room. Take the thermometer out of the water. What is the result? The mercury falls 2 or 3 degrees and then rises again to its original height. Try this again, moving the thermometer backwards and forwards quickly in the air. The mercury falls even more. What do you conclude? Surely that the quicker the water evaporates the colder it becomes. Does water evaporate at the same rate on all days? No, you have already found out that the drier the day the more quickly water evaporates. What, then, will happen to this wet bulb thermometer on dry days? Will not the water evaporate more quickly and the mercury therefore sink a greater number of degrees? What would you expect on damp days? Exactly the opposite. The sea-weed will indicate

conclusions you have arrived at from these results.

63. Weigh some sea-weed, tied up in a muslin bag, every morning, and record the result in your book. Represent the result graphically on squared paper.[1]

64. Take the readings every morning of the barometer and wet and dry bulb thermometer; note down also the direction of the wind and the state of the weather.

Consider each of these records separately. State your conclusions about each. For instance, does the barometer rise or fall in wet weather? Does the sea-weed weigh less or more under these conditions? What about the wet and dry bulb thermometer? Which wind seems to favour rain most? and so on.

§ 32. **Evaporation of (1) Ordinary water, (2) Sea water, (3) Rain water.**—You have already seen that when water is boiled and also when it is left exposed to air even at ordinary temperatures, it passes away in the form of vapour. In the former case you observed that any solid matter, such as salt, etc., did not pass over with the vapour, but was left behind in the vessel. Ought you not in this way to be able to ascertain the amount of solid matter contained in any water?

EXPERIMENT 29.—Find out roughly the amount of solid dissolved in rain and tap water by evaporat-

[1] All the squared paper used in depicting the various results in the [illegible]

ing a few cubic centimetres of each on a clock glass over a water bath.

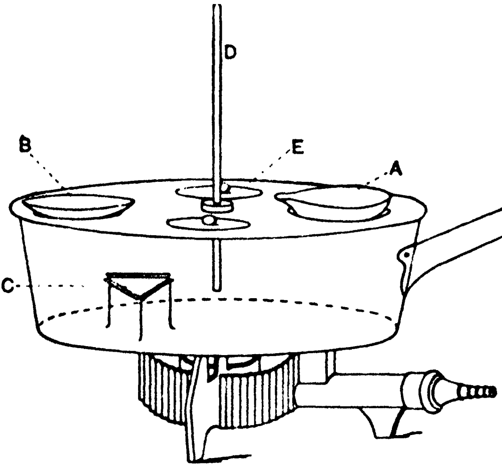



FIG. 26.—The Water Bath.

The above figure represents a simple form of water bath which can also be used as an air bath or oven. It consists of an ordinary saucepan, in the cover of which are four openings for evaporating dishes A, or clock glasses B. The whole can be heated to the temperature of boiling water, by water contained in the saucepan. The covers E, should be placed over any of the openings not in use. A glass tube D, inserted in a cork and almost touching the bottom, readily shows if the water is getting too low by the appearance of steam at its upper end. The appearance of the steam of course indicates that the level of the water has sunk below that of the tube, and that more water is required. When a higher temperature is desired, D is replaced by a thermometer and the saucepan used without water. Evaporating dishes, etc., can be heated as before or on small pipe-clay triangles C, placed in the saucepan itself. When the bath is used without water, the temperature must of course be first carefully regulated by watching the thermometer and turning down the gas as required.

Which contains the most solid matter?

How can you find out the exact amount of solid? By weighing, of course. The porcelain evaporating

dishes should be used in doing this quantitatively, *i.e.* in ascertaining the exact amount dissolved.

EXPERIMENT 30.—Weigh a dry evaporating dish, then measure into it 100 cc. of the liquid and evaporate to dryness over the water bath. On re weighing the increase indicates the amount of solid dissolved in 100 cc. of the liquid.

Here is an example—

| | | |
|---|---|---|
| Weight of dish + residue | . | 30·45 grams |
| Weight of dish | . . | 30·35 grams |
| Residue | . . | ·10 gram. |

100 cc. therefore contained ·10 gram, and 1000 cc. (*i.e.* a litre) would contain ·10 × 10 = 1·00 gram.

EXERCISE

65. Ascertain quantitatively the amount of solid contained in—

(*a*) 100 cc. of tap water,
(*b*) 100 cc. of rain water,
(*c*) 20 cc. of sea water,

and then calculate the amount of solid dissolved in 1 litre of the above waters (a litre = 1000 cc.)

## SOLUBILITY

**§ 33. Solubility of salt, soda, chalk, etc., in water.**—Could you not make use of this method to ascertain the amount of salt, soda, etc., which water can dissolve, *i.e.* their solubility in water?

EXPERIMENT 31.—Powder these substances[1] and add them separately to water (about 200-300 cc. or more) in bottles, then shake well. There must be sufficient of the solid to allow some to remain undissolved even after standing during a day or two (*i.e.* the liquid is to be saturated).

Filter the liquids separately, noting their temperature.

Evaporate 20 cc. of each over the water bath, and ascertain the amount of solid residue. Calculate the amount dissolved in 100 cc., and represent the results graphically on squared paper.

## EXERCISES

66. Find out the solubility in water of salt, washing-soda, black-board chalk, sand, etc., at ordinary temperatures.

67. Ascertain whether mud or earth contains any solid soluble in water. To do this shake up some earth with water and filter, then evaporate the filtrate and ascertain the amount of residue.

68. Make a graphic representation of the solubilities in water of the solids used in Exercise 66.

[1] One experiment should be done before the class by way of illustration, and the rest by the scholars themselves.

# APPENDICES

## Notes on Cutting Glass, Boring Corks, etc.

*To cut a glass tube or rod.* Scratch the glass with a three-cornered file at the point required, and then holding it in a cloth with the scratch between the two hands, slightly bend it. If it does not break easily, file deeper.

*To bend glass tubing.*—Turn the tube constantly round in an ordinary batswing gas flame (not a bunsen) so as to heat two or three inches of the tube until it *becomes soft and pliable*, then take it out of the flame and bend as required. The bend should not have a flattened appearance and should be of the same bore as the rest of the tube.

*To bore a cork.*—A cork is bored by means of the cork borers shown in the illustration. Select one of the brass tubes, which should be slightly smaller than the glass tube for which the hole is required. After inserting the brass rod into the holes at the top of the borer, gradually screw the borer into the cork, *at the same time turning the cork in the opposite direction.* By this means a hole can be drilled quite straight through the cork. The final fitting of the glass tube to the hole should be done by means of the round file.

FIG. 27.

*The* T *piece* will be found useful when two gas jets are required at the same time. The india-rubber tubing

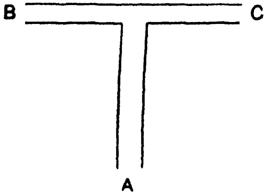



FIG. 28.

supplying the gas is connected to A, and a burner to each of the open ends B and C.

## LIST OF APPARATUS REQUIRED

1 Spirit lamp, 4 oz. glass.
1 Bunsen's burner, $\frac{3}{8}$ in., and rose.
2 Clips, $\frac{3}{4}$ in.
6 feet india-rubber tube, $\frac{5}{16}$ in.
2 Pipe-clay triangles, large.
4 Conical flasks, 3 oz.
2 India-rubber corks, $\frac{7}{8}$ in., 1 hole.
2 India-rubber corks, $\frac{7}{8}$ in., 2 holes.
2 lbs. Glass tubing, $\frac{3}{16}$ to $\frac{3}{8}$ in.
2 feet each india-rubber tube, $\frac{1}{8}$ and $\frac{3}{16}$ in. diameter.
2 Plain funnels, $3\frac{1}{2}$ in., glass.
1 Packet Rhenish filter papers, $18\frac{1}{2}$ cm., 595.
4 Royal Berlin porcelain basins, 4 in. diameter.
4 Bohemian glass flasks, 8 oz.
2 Nest's Bohemian glass beakers, Nos. 1 to 4.

1 Thermometer, 200° C., $\frac{1}{4}$ in. diameter.
1 Thermometer, 220° F., $\frac{1}{4}$ in. diameter.
4 dozen Corks, assorted.
1 Brass T piece, $\frac{3}{8}$ in.
1 pair Iron tongs with bow, 6 in.
1 Condenser, 12 in.
1 Retort stand, 15 in., and clamp with right and left screw.
3 Becker's balances, No. 66.
3 each Sets, weights and forceps.
1 each Sets, weights, $\frac{1}{2}$ to 200 grains.
1 Fletcher's Argand burner, $\frac{3}{4}$ in., fig. 201.
1 Graduated measure, 100 cc.
1 Barometer tube.
1 set (6) Cork borers.
1 each File, round and triangular, 4 in.
1 Tripod, 6 × 4 in.
1 Iron bath with lid, special.
2 pieces Wire gauze, 6 × 6 in.
2 oz. Copper wire, No. 18.
3 lbs. Mercury.
2 Boxwood lever with fulcrum.
1 set (8) Cubes of wood, 2 cm.
1 set (8) Cubes of wood, 4 cm.
2 dozen Boxwood rules, 12 in., divided in cms. and $\frac{1}{10}$ths, and in inches and $\frac{1}{10}$ths.
1 dozen Stoppered bottles, 4 oz.
1 set (6) Wooden block supports.
1 pair Hand-bellows, small.
1 Board for mounting barometer tube with brass scale, 4 in., divided in $\frac{1}{10}$ths, 28 to 32 in.
2 dozen Ordinary test tubes.
2 dozen Boiling tubes.
8 Cubes of wood, 1 in., fitted in box.
1 Wet and dry bulb thermometer.
Sea-weed.
2 pints Sea-water.
3 Specific gravity tables.

4 Clock glasses, 4 in.
1 Reel fine iron wire.
3 N. M. stoppered bottles, 2 oz.
burner.

Messrs. Townson and Mercer, of 89 Bishopsgate Street Within, London, E.C., will supply the above set of apparatus, complete in a packing-case, for £11, and with only 2 balances and weights for £8 : 18s.

Extra rulers can be obtained at 1s. 10d. per dozen.

Where it is considered desirable that extra quantities of apparatus, etc., should be supplied, they will be charged at Catalogue prices.

END OF PART I

*Printed by* R. & R. Clark, *Edinburgh*